

A Review: Edible Mushrooms as Source of Dietary Fiber and its Health Effects

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ABSTRACT

Dietary fibers are high molecular weight materials which are resistant to digestion and absorption in human beings but it can move along with food through the digestive system absorbing water. Chemically, dietary fiber consists of plant components such as cellulose, lignin, waxes, chitins, pectins and β -glucans. Edible mushroom is considered as a novel source of dietary fiber. Mushroom contains dietary fibers belonging to β -glucans, chitin and hetero polysaccharides as much as 10–15 % in the dried matter. The dietary fiber content and composition in edible mushroom vary greatly with its morphological stages including fruit body, mycelium and sclerotium. Sources of dietary fiber are usually divided into categories of “insoluble” and “soluble”. Insoluble refers to lack of solubility in water, with attracting properties that help to increase bulk, soften stools and shorten transit time through the intestinal tract. Soluble fiber undergoes active metabolic processing via fermentation that yields end products with broad, significant health effects. Dietary fibers compose the major component of products with low energy value that have had an increasing importance in recent years. Its components organize functions of large intestine and have important physiological effects on glucose, lipid metabolism and mineral bioavailability. It shows the protective effect against gastrointestinal diseases, constipation, hemorrhoids, colon cancer, rectum cancer, ulcer, diverticulitis, obesity, diabetes, stroke, blood cholesterol, hypertension and cardiovascular diseases. The present review analyses the different sources of dietary fiber from edible mushrooms and their important implications on human health.

Keywords: Dietary fiber, digestion, absorption, edible mushroom, obesity, cardiovascular diseases.

1. Introduction

Generally, dietary fiber (DF) was defined as the portions of plant foods that were resistant to digestion by human digestive enzyme; this included polysaccharides and lignin. More recently, the definition has been expanded to include oligosaccharides, such as inulin and resistant starches [1]. The American Association of Cereal Chemists (AACC) defines that DF is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine as well as having beneficial physiological effects such as laxation, blood glucose attenuation and/or blood cholesterol attenuation [2]. Carbohydrates is divided

into two basic groups based upon their digestibility in the Gastro Intestinal tract. The first group (i.e. starch, simple sugars and fructans) is easily hydrolysed by enzymatic reactions and absorbed in the small intestine. These compounds are known as non-structural carbohydrates, non-fibrous polysaccharides (NFC) or simple carbohydrates. The other group (e.g. cellulose, hemicelluloses, lignin, pectin and beta-glucan) are resistant to digestion in the small intestine. These compounds are called complex carbohydrates, non-starch polysaccharide (NSP) or structural carbohydrates. NSP can be further subdivided in to two general types of soluble and insoluble. This subdivision is based on physical, chemical and functional properties. Soluble fiber dissolves in water forming viscous gels. Some hemicelluloses, pectin, gums and inulin-type fructans are soluble fiber. The insoluble fibers are not water soluble in the human GI tract. They cannot form gels due to their water insolubility and fermentation is limited. They consist of lignin, cellulose and some hemicelluloses [3].

2. Mushrooms as source of DF

Edible mushroom is considered as a novel source of dietary fiber due to the presence of non-starch polysaccharides. The known constituents of dietary fiber are given in Table 1[4]. Total dietary fiber (TDF) in mushrooms is the sum of intrinsic non-digestible carbohydrates, mainly chitin [5]. Mushroom glucans are also components of soluble (SDF) or insoluble (IDF) dietary fibers [6]. Their solubility in water depends on molecular structure and conformation. Glucans bound to chitin or to proteins are generally insoluble in water.

Mushroom cell walls are major source of DF. It contains chitin (a straight-chain (1→4)-β-linked polymer of *N*-acetyl-glucosamine) and the polysaccharides such as (1→3)-β-D-glucans and mannans respectively [7]. The mushroom cell wall components are non-digestible carbohydrates (NDCs) that are resistant to human enzymes. The major component of mushroom is carbohydrate and total content ranges from 35% to 70% dry weight in different mushroom species (Table-2) [8, 9]. Most of the carbohydrates in

Non Starch polysaccharides and oligosaccharides	Analogous carbohydrates	Lignin substances associated with the NSP and lignin complex
Cellulose	Indigestible dextrans	waxes
Hemicellulose	Resistant maltodextrins	phytate
Arabinogalactans	Synthesized carbohydrates	saponins
Polyfructoses	Polydextrose	suberin
Inulin	methyl cellulose	tannin
Oligofructans	Hydroxypropylmethyl cellulose	
Galacto-oligosaccharides	Resistant starches	
Gums, mucilages, pectins		

Table 1. Components of dietary fiber according to the American Association of Cereal Chemists.

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mushrooms are NDCs including oligosaccharides and cell wall polysaccharides such as chitin, β -glucans and mannans. The amount of chitin (% dry matter) found in different mushrooms is usually low than β -glucans [10].

Species	Common names	Crude protein	Crude fat	Carbohydrate	Crude fiber	Ash
<i>Grifola frondosa</i>	Maitake	21.1	3.1	58.8	10.1	7.0
<i>Lentinus edodes</i>	Shiitake	13.4-17.5	4.9-8.0	67.5-78.0	7.3-8.0	3.7-7.0
<i>Pleurotus ostreatus</i>	Oyster Mushroom	10.5-30.4	1.6-2.2	57.6-81.8	7.5-8.7	6.1-9.8
<i>Tricholoma giganteum</i>	Matsutake	16.1	4.3	70.1	4.5	5.0
<i>Volvariella volvacea</i>	Straw Mushroom	30.1	6.4	50.9	11.9	12.6

All data presented as percentage of dry weight; The crude fiber contains mainly the water-insoluble fiber fraction.

Table 2. Proximate composition of some common mushroom species

Species	Pilei			Stems		
	TDF	IDF	SDF	TDF	IDF	SDF
<i>Pleurotus ostreatus</i>						
Strains-77	63.1	56.3	4.6	53.6	46.7	4.9
Strains-70	59.9	51.4	4.3	64.8	61.4	3.3
Strains-L22	34.5	31.8	2.7	38.9	36.9	2.0
Strains-137	36.5	31.8	4.7	48.6	44.4	4.2
<i>Pleurotus eryngii</i> (non specified)	36.7	29.2	2.0	45.7	44.3	3.3

(TDF-total dietary fiber; IDF-insoluble dietary fiber; SDF-soluble dietary fiber)

Table 3. Contents of dietary fibers in pilei and stems of *P. ostreatus* (strains 77, 70, L22, 137) and *P. eryngii* (non specified).

Species	Pilei		Stems	
	α -glucan	β -glucan	α -glucan	β -glucan
<i>Pleurotus ostreatus</i>				
Strains-77	4.3	37.2	3.0	43.3
Strains-70	7.9	39.2	7.6	50.0
Strains-L22	4.4	27.4	5.1	32.5
Strains-137	3.4	30.7	3.8	37.6
<i>Pleurotus eryngii</i> (non specified)	4.3	20.4	3.6	39.1

Table 4. Contents of α -and β -glucans in pilei and stems of *P. ostreatus* (strains 77, 70,

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L22, 137) and *P. eryngii* (non specified).

The dietary fiber contents in dry matter in the fruit bodies of both *Pleurotus ostreatus* and *Pleurotus eryngii* (pilei and stems separately) are given in Table 3 [11,12]. The stems contain higher amount of IDF than the pilei where as amount of SDF in the pilei is comparable with stems. But an exception was strain 77 of *P. ostreatus* showing reciprocal relations.

The amount of α -glucan and β -glucan in stem and pilei of *P. ostreatus* and *P. eryngii* are given in Table 4. The stems content more β -glucans than the pilei in all strains of mushroom species [13, 14, 15].

3. Health effects of DF

Most of the fiber containing foods contains approximately one-third soluble and two-third insoluble fiber [16]. The dietary fiber intake is related to age, gender and energy intake. The general recommendation for adequate intake (AI) is 14g/1000Kcal [17]. The AI includes NSPs, analogous carbohydrates (e.g. resistant starches), lignin and associated substances [18]. The recommended daily DF intake is 36g/day for adult men and 28g/day for adult women.

3.1. Cardiovascular

Cardiovascular diseases (CVD) including coronary heart disease (CHD), stroke and hypertension affect more than 80 million people. CHD was the leading cause of death and strokes were the third leading cause of death in the United States in 2005 [19]. CHD is the most prevalent cause of death due to lifestyle practices such as diet, physical activity and cigarette abuse [20].

Higher intakes of DF compared to lower consumption levels are associated with significantly lower prevalence rates for coronary heart diseases, strokes and peripheral vascular diseases [21]. With the highest levels of fiber consumption of a person have a 29% lower risk for CHD than those with the lowest intakes. More recent studies found that for every 10g of additional fiber consumption the death risk of CHD decreased by 17-35%. The mechanisms behind DF and CHD prevention are: First, soluble fibers reduce serum total and LDL cholesterol with increasing the rate of excretion of bile. Second, it has been shown that production of short chain fatty acid can inhibit cholesterol synthesis. Third, DF shows the ability to regulate energy intake and maintain the body weight enhancing the weight loss. Fourth, DF has been shown to lower the risk for type two diabetes through glycemic control or reduced energy intake. Five, DF has been shown to decrease circulating levels of C-Reactive Protein (CRP), a marker of inflammation and a predictor for CHD.[3]. The reduction of serum triglyceride levels may be due to decrease the absorption of fat from the small intestine. The four major water-soluble fibers, β -glucans, psyllium, pectin and guar gum can lower serum LDL cholesterol concentration without affecting HDL cholesterol or triacylglycerol concentrations [22].

3.2. Obesity

DF has many functions in diet, one of which may be to aid in energy intake control and reduced risk for development of obesity. There are multiple factors that could contribute to obesity; the primary cause is due to an increase in energy absorption, energy

expenditure ratio. Increasing the consumption of DF may decrease energy absorption by way of diluting a diet's energy availability [23]. This weight loss was primarily due to decreased body fat. DF may decrease a diet metabolizable energy (ME) that is gross energy minus the energy lost in the feces, urine and combustible gases [24]. Both soluble and insoluble fiber may play a more important role for weight loss during consumption of a high fat diet.

3.3. Diabetes

Type-2-diabetes has increased over the past several years by 61% [25]. This Diabetes results from decreased insulin sensitivity and hyperglycemia. Increasing free fatty acids (FFA) in blood can inhibit glucose metabolism through the inhibition of GLUT4 transporters [26]. Short chain fatty acids, by way of decreasing serum free fatty acids, may reduce blood glucose levels through competition in insulin-sensitive tissues.

Species	Polysaccharide	Health effects
<i>Agaricus blazei</i>	α -(1→4)-: β -(1→6)- glucan α -(1→6)-: α -(1→4)- glucan β -(1→6)-: β -(1→3)- glucan β -(1→6)-: α -(1→3)- glucan β -(1→2); β -(1→3)-glucomannan	Immune system stimulant, promoting body's natural defense mechanisms to fight a variety of infectious agents including cancer.
<i>Grifola frondosa</i> (Maitake)	β -(1→3): β (1→6)glucan Mannoxylglucan Xyloglucan Mannogalactofucan	Cytotoxic affect on human prostate cancer cells(PC9)
<i>Lentinus edodes</i>	β -(1→3): β -(1→6) glucan. Galactoglucomannan	Anticancer effect on gastric and colorectal carcinomas
<i>Schizophyllum commune</i>	β -(1→3)-glucan	Increase overall survival of patients with head and neck cancers
<i>Pleurotus sajor-caju</i>	β -(1→3)-glucan Xyloglucan Mannogalactoglucan Mannogalactan Glucoxytan	Protein-containing polysaccharides show strong anti tumor activity
<i>Pleurotus citrinopileatus</i>	Arabinogalactan (1→3)- β -D-glucan.	Protein-containing hetero polysaccharides show strong anti tumor activity
<i>Pleurotus ostreatus</i>	HA β -glucan	strong anti tumor activity
<i>Trametes versicolor</i>	β -D-glucans, polysaccharide-protein complex (PSPC).	Prevents liver cancer, useful for hepatitis B & chronic active hepatitis.

Table 5. Chemical structures of polysaccharides from different mushroom species and their health effects.

3.4. Gastrointestinal

Dietary fibers affect the entire gastrointestinal tract. DF can increase responses of gastrointestinal hormones that serve as incretins to stimulate insulin release and affect appetite [27]. In colon, fermentable fibers increase health-promoting bacteria such as *Lactobacilli* and *Bifidobacteria* [28]. Serum cholesterol and lipoprotein concentrations can be reduced in humans and animals by β -glucan-rich diets due to greater excretion of bile acids [29]. The consumption of DF decrease the prevalence of gastroesophageal reflux disease (GERD), peptic ulcer, gallbladder disease, appendicitis, colorectal cancer and hemorrhoids[30].

3.5. Anti cancer and immunomodulator agents

Edible mushrooms are rich in DF with non-digestible carbohydrates (NDCs) including β -glucans, polysaccharide-protein complexes (PSPC) and that has a wide range of health benefits to humans. These mushroom DF are used as an immune-enhancing and antitumor materials as well as in blood glucose and lipid attenuation [10,31-35]. Selective prebiotic fiber sources, such as resistant starches, inulin, few oligosaccharides act as specific substrate for bacteria that produce specific short-chain fatty acids (SCFA) and can lower the intestinal pH. The SCFA butyrate has been shown to increase apoptosis in human colonic tumor cell lines. Increasing the numbers of *Bifidobacteria* in the colon and reducing intestinal pH has a direct effect on carcinogenesis in the large intestine. Decreasing the amount of pathogenic bacteria in colon, the number of production of carcinogenic substances is reduced [36]. Some commercial polysaccharides (β -glucans) as well as PSPC from different mushroom species were shown to stimulate the immune system in animals and humans to inhibit cancer cell proliferation [31]. They are known as immunomodulator and have been used as adjuvant in cancer therapy [37-39]. The health effects of some mushroom polysaccharides are given in Table 5 [40-52].

4. Conclusion

In general, a dietary fiber is high molecular weight carbohydrate which is resistant to digestion and absorption in human beings but it can move along with food through the digestive system absorbing water. Chemically, dietary fiber consists of cellulose, lignin, waxes, chitins, pectin, β -glucans and hetero polysaccharides. Edible mushrooms are novel source of DF. The fruit bodies of *P. ostreatus* and *P. eryngii* contain significant amounts of β -glucans that are components of both IDF and SDF. The amount of IDF and SDF in the fruit bodies of mushrooms vary with the strains and species. The stems are better source of IDF and β -glucans than pilei. The high level consumption of fiber rich diets has health-protective effects and disease-reversal benefits. The high quantity of DF intake can decrease the risk of developing gastrointestinal diseases, constipation, hemorrhoids, colon cancer, rectum cancer, ulcer, diverticulitis, obesity, diabetes, stroke, blood cholesterol, hypertension and cardiovascular diseases.

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